

# **BUBBLES - An Automated Decision Support System for Final Approach Controllers**

**Zhizang Chi  
Massachusetts Institute of Technology  
Cambridge, MA**

## **Assumptions-**

1. An explicit Schedule exists for landings (and takeoffs) at each runway.
2. Each aircraft has declared an IAS for final approach and will be obligated to fly it as accurately as possible.
3. There is a continuous estimate of average windspeed on approach.

## **Objective-**

**PROVIDE AUTOMATED CUES TO ASSIST  
CONTROLLERS IN THE SPACING OF  
LANDING AIRCRAFT**

The Cues have the following characteristics:

1. The cues are adaptive to estimation errors in position and speed by the radar tracking process, and piloting errors in execution of turns and commanded speed reductions.
2. The cues are responsive to the desires of the human controller;  
  
e.g., change landing sequence, insert a missed approach anywhere, insert planned take-offs between landings, increase/decrease spacing for any particular aircraft

The "merging area"

for aircraft arriving from different directions is on the runway centerline at 9-20 nm. from the runway. The schedule of landings and takeoffs is represented by a set of landing "bubbles" and takeoff "triangles" which move towards the runway at different approach speeds. Landing aircraft will intercept their bubble at different points on the extended runway centerline within the merging area.

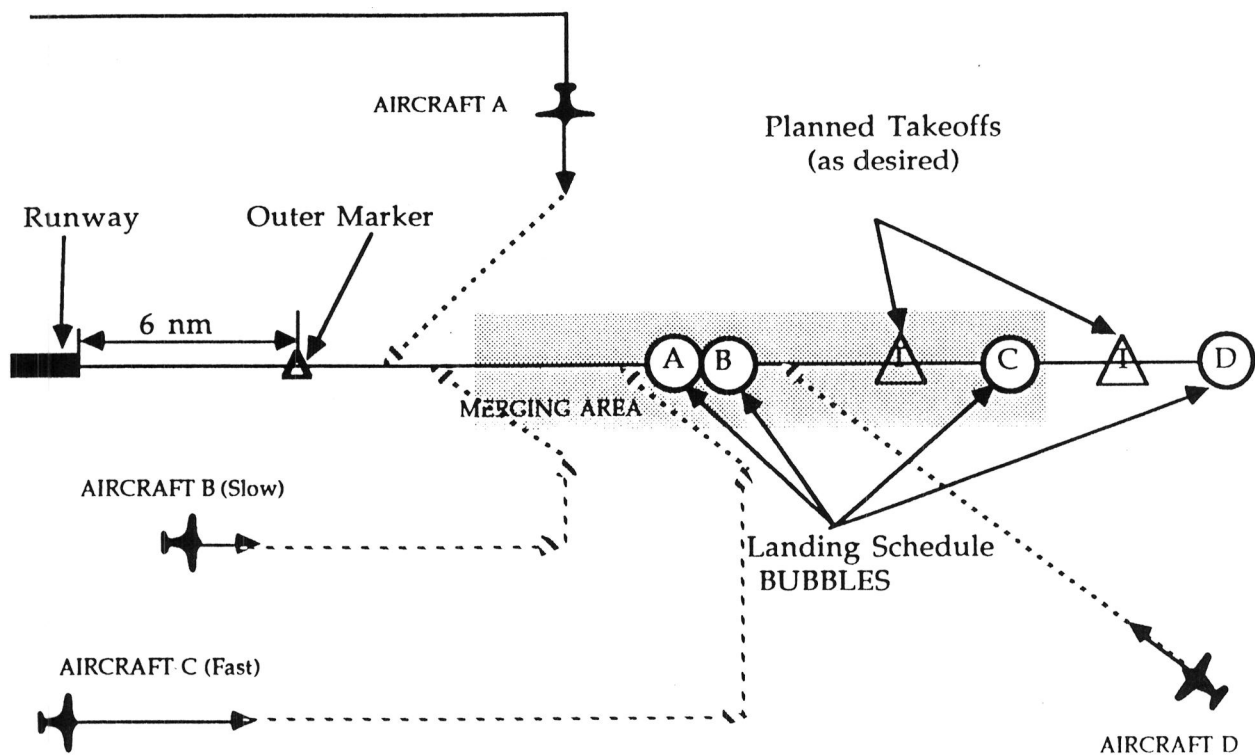


Figure 1- Region of Final Traffic Merging and Spacing

There are three planned spacing commands currently:

C1 - Turn to Base Leg

C2 - Turn to Intercept Leg

C3 - Reduce to Final Approach IAS

Cues are given for certain "spacing" commands for arrivals from different directions. At present, there are three such commands. A blinking cue gives a countdown to issue the command and anticipates the reaction time to execute.

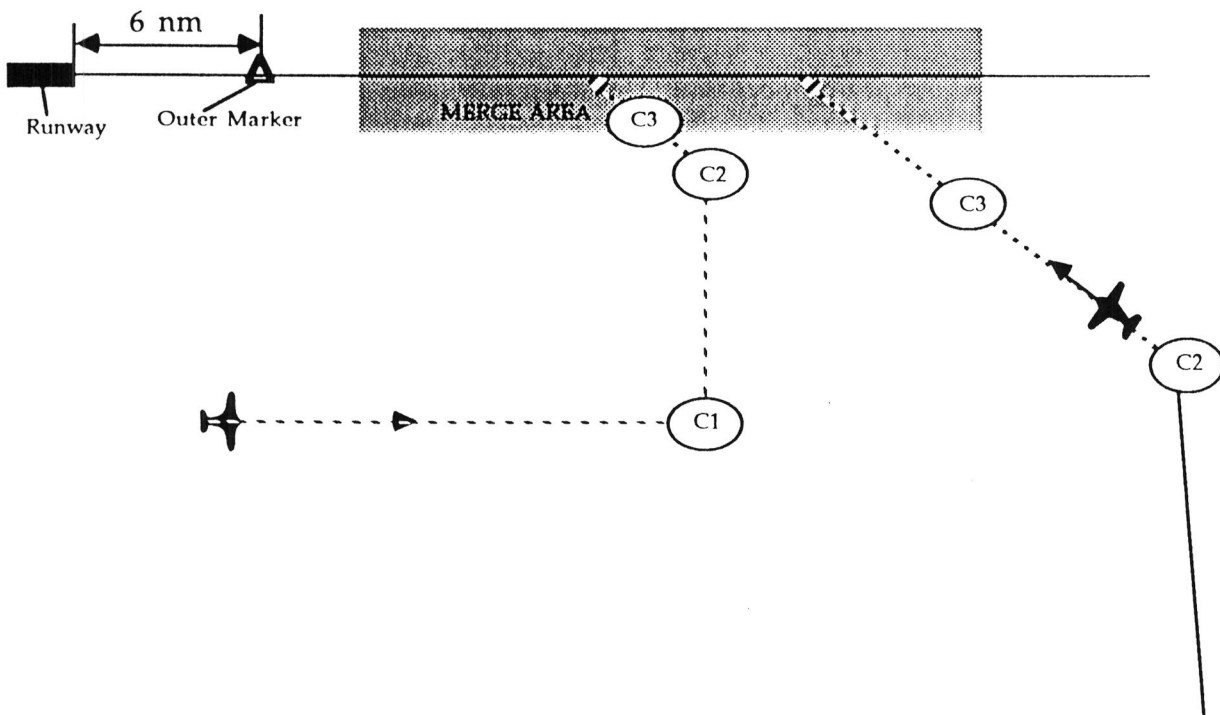
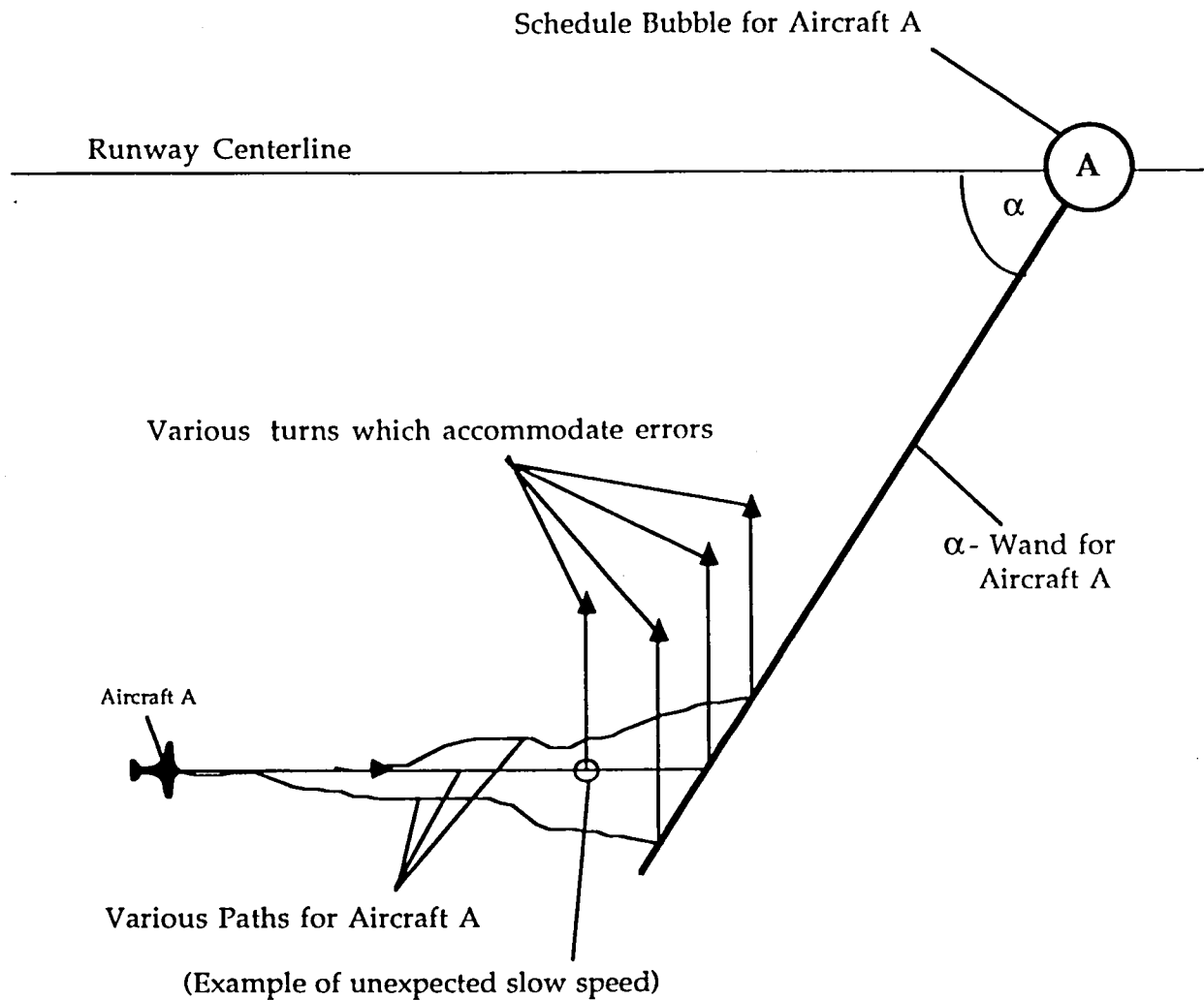


Figure 2 - Cueing of Spacing Commands

The correct Command is called whenever the aircraft reaches the  $\alpha$ - wand. The angle  $\alpha$  is constant given the final IAS for each aircraft. The aircraft can wander in speed and direction, but the correct cue is made whenever it reaches the wand. Wands will not be displayed to controllers.



**Figure 3 - Error Accommodation of the  $\alpha$ -Wand**

$\beta$  remains a constant for correct spacing on the Base Leg. In this cue, the wand overtakes the aircraft at the correct time to turn to the intercept leg.

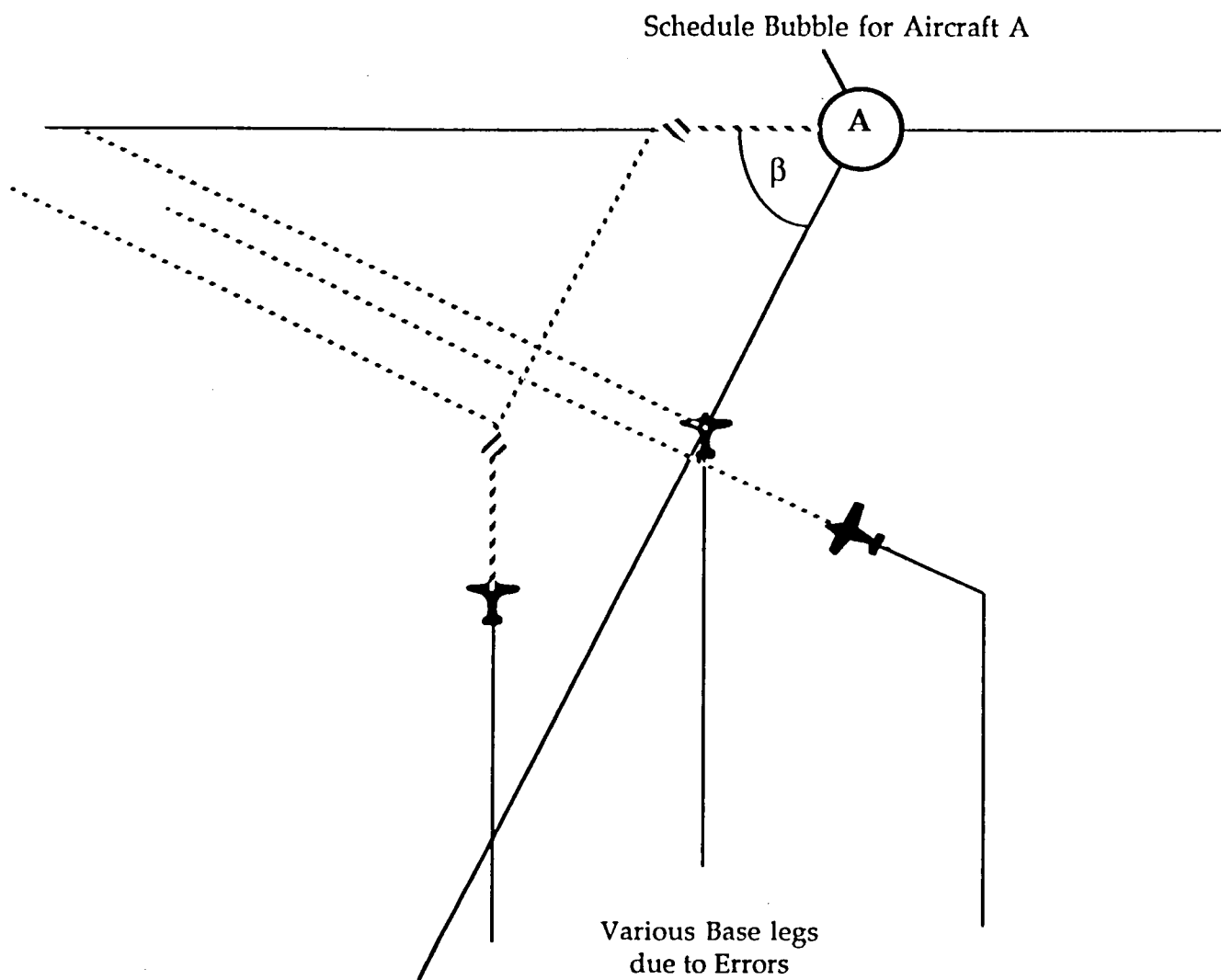


Figure 4 - Error Adaptation for the  $\beta$  - Wand

Speed Reduction called when aircraft catches up to the  $\gamma$  -wand on the intercept leg close to the runway centerline. Aircraft are kept above their declared final approach speed by 10-20 knots during earlier maneuvering. Wind speed on approach must be continuously updated.

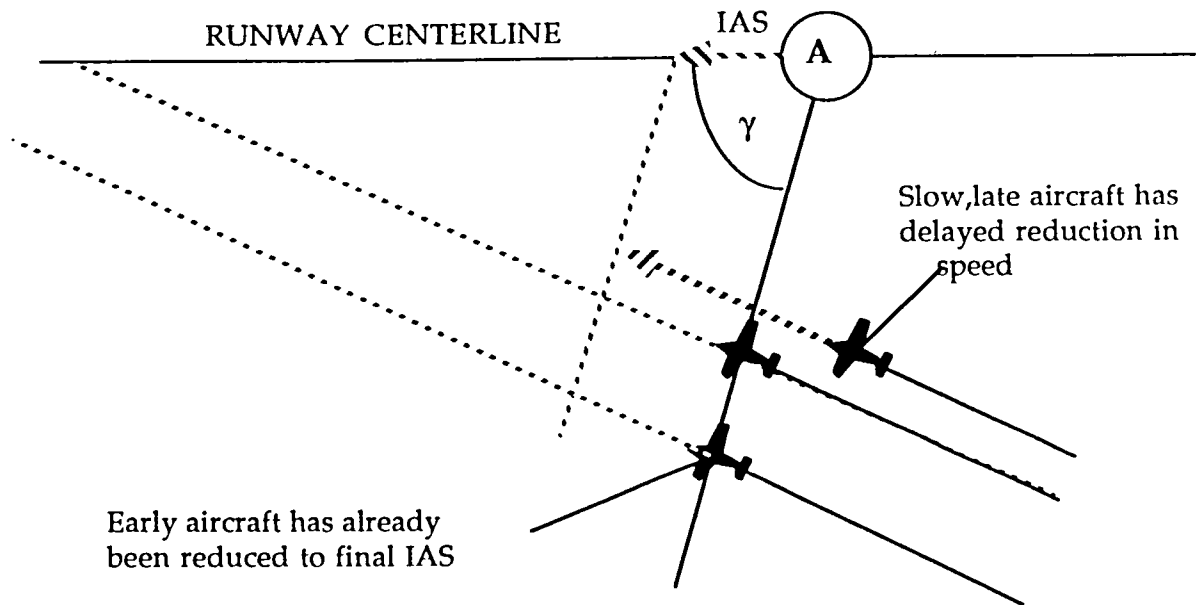
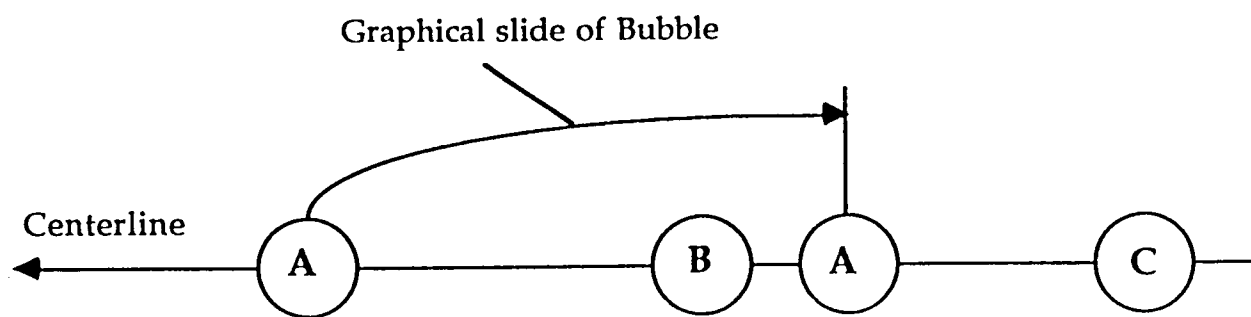


Figure 5 - Error Adaptation for the  $\gamma$  -Wand

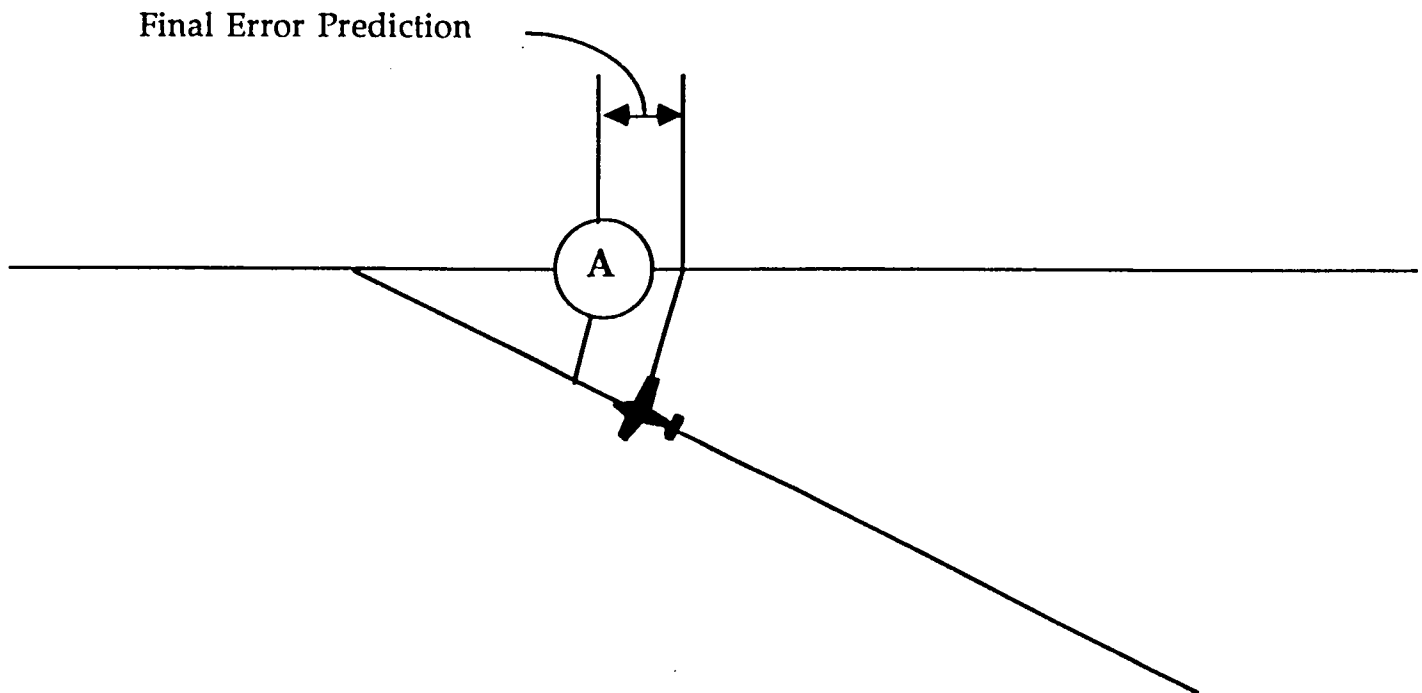
Any Bubble can be selected and moved graphically to a new position by the Controller. The Spacing Cues will automatically adjust. The Bubble will blink or change color if the move is not feasible.

A complete slide of all subsequent aircraft can also be done. The planned insertion of waiting takeoff aircraft can be displayed during moves of landing aircraft. The planned landing schedule can be set to automatically insert another aircraft by a small opening of the landing spacing. This maximizes total operational rate of the runway.



**Figure 6 - Changing the Desired Sequence or Spacing**

Currently, we are introducing a method of automatic adaptation to any residual errors between the aircraft and the bubble as the aircraft reaches the runway centerline.



**Figure 7 - Adaptation to Centerline Errors**

Final Error causes an automatic shift of bubble to actual aircraft position if late and, if necessary, automatically shifts all subsequent bubbles within the limits of their feasible moves. This keeps the scheduled bubble positions tied to actual performance of the aircraft over a longer period.